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Journal of the Society of Arts.

FRIDAY, AUGUST 20, 1869.

Announcements by the Council.

Examinations, 1870.

The Council have this year decided to remove from the Programme those subjects in which the Science and Art Department holds examinations, which, it appears, are now largely taken advantage of by the same class of persons (and very often by the same individuals) as those who sit at the Society's examinations. The following subjects will therefore not appear in the programme for 1870:—

Algebra.
Geometry.
Trigonometry.
Conic Sections.
Navigation, &c.
Principles of Mechanics.
Practical Mechanics.
Magnetism, Electricity, &c.
Light and Heat.
Chemistry.
Mining and Metallurgy.
Botany.
Animal Physiology.
Free-hand Drawing.
Practical Geometry.
Mechanical Drawing.

Owing to a prize of £5 having been kindly offered by Earl Fortescue, President of the British Branch of the International Decimal Association, the subject of the Metrical System will be retained.

The programme is now in preparation, and will include some further modifications in the system, but the above, being by far the most important, are announced at the earliest opportunity.

Improved Cabs.

The Council of the Society of Arts offer the following medals for improved hackney carriages specially suited to the metropolis:—

The Society's Gold Medal for the best and most convenient open hackney carriage for two persons.

The Society's Silver Medal for the second-best ditto.

The Society's Gold Medal for the best and most convenient closed hackney carriage for two persons.

The Society's Silver Medal for the second-best ditto.

The Society's Gold Medal for the best and most convenient hackney carriage for four persons, either open or closed, or both.

The Society's Silver Medal for the second-best ditto.

Lightness of construction, combined with adequate strength and durability, will be especially considered in making the awards.

The awards will be made after actual trials of the carriages extending over a certain period.

Communications describing the carriages must be sent to the Secretary of the Society of Arts before the 1st January, 1870, the carriages to be sent to a place hereafter to be appointed.

The Council also offer the Society's Silver Medal for the best instrument, to be affixed to a cab or other hackney carriage, for indicating the fare as between the passenger and the driver, whether by registering the distance travelled or otherwise, and which instrument shall also indicate, for the convenience of the cab-owner and of the driver, the total distance travelled during the day and the total amount earned. The instruments competing, with full descriptions of their construction, to be sent to the Society's House before the 1st January, 1870.

Competitors may, at their option, sign their communications, or may forward with them sealed letters containing the name and address of the writer.

The Council reserve to themselves the right of withholding all or any of the medals, *in case* none of the carriages or instruments possess, in their opinion, sufficient merit.

Subscriptions.

The Midsummer subscriptions are due, and should be forwarded by cheque or Post-office order, crossed "Coutts and Co.," and made payable to Mr. Samuel Thomas Davenport, Financial Officer.

Proceedings of the Society.

Cantor Lectures.

ON APPLIED MECHANICS.

By John Anderson, Esq., C.E.

Lecture IV.—Delivered Monday, May 3rd.

Applied Mechanics in relation to Natural Power.

This lecture will relate to that part of the subject of applied mechanics concerning motion, as derived from the power or force in nature, which comes within the province of the mechanical engineer—more especially to the natural mechanical force which is stored up for him to take advantage of, and turn to practical account.

Although the science of mechanics, both theoretical and practical, is founded on the recondite and unalterable laws of motion, still, in the present lecture, in order to make this part of the subject intelligible to a general audience, all reference to the numerous laws of matter in motion will be avoided, except where necessary for reference or explanation of the part of the subject in hand.

The numerous mathematical discoveries and philosophical investigations of the laws of motion which have been made in past ages, and which are still being made at the present time, have so thoroughly laid bare the fundamental principles by which all the movements in applied mechanics are produced and governed, and so many excellent books have been written thereon, that, in the practical applications of mechanical science, many of us are scarcely conscious of the assistance rendered in the daily routine of the busy workshop. Men are apt to forget from whence all this invaluable knowledge has come for our guidance, and although simple as some of them may appear, from our every-day familiarity with them, yet every one of those grand truths was the result of deep thinking, and due to the closest study of some learned philosopher, and the discovery of each, one after the other, marked a new stage in the progress of practical as well as theoretical science.

For similar reasons, it will neither be necessary nor expedient to refer to the innumerable detail of mechanism by which the power of nature is applied and turned into mechanical work, yet it would be extremely interesting to some if we could trace the gradual invention of many of our most familiar appliances, step by step, such as those gearing contrivances for receiving force or motion, for accumulating force for expending force, for regulating force and such like. Simple inventions such as toothed-wheels, a revolving shaft, or a spindle, or a clutch, the fast and loose pulleys, a cam, a pair of rollers, or the fly-wheel, have each been of great value to the industrial world, and all of them, together with such small inventions as the bolt and nut, have severally produced a much greater effect upon the world's destiny than many things with a more sounding title.

Placed as we are on the surface of this wonderful little world, and from the limited nature of our senses, we are prone to consider everything that we see around us as though they were naturally in a state of absolute rest, but in reality there is no such condition as positive rest in this part of the universe. Not only are suns and planetary systems in a condition of whirling motion, but air and water, and indeed everything upon the earth's surface is also in a state of restless activity. An iron bridge, or even a machine in a factory, when the steam-engine is not working, may both seem to be at rest; but the close investigation of physics tells us that it is the contrary—that gravitation and heat are always at work, either amongst the atoms or molecules, or in disturbing the condition of larger bodies. The bridge is always on the move, and if such a condition as rest should exist for a moment, it is because the forces at work are in an accidental condition of equilibrium.

As to what the real and ultimate nature of force is, we know not; but in considering the sensible motion of bodies in the operations of applied mechanics, or those with which we have to deal and are familiar, it will be found that all motion is the result of some extraneous but mysterious force disturbing equilibrium, and a close examination only goes to show that almost all the force which the engineer has to deal with and apply is, so far as we are concerned, primarily derived from the heat of the glorious sun; but we are not able to trace it farther, or to say what it is, beyond the effect which it produces.

When any single force acts upon a body, motion in a straight line is produced; such is the action of gravitation through space. The steam-hammer is lifted in a straight line by the force of heat in the condition of steam, and, when left to itself, by the natural law of gravitation the hammer falls in a straight line towards the centre of the earth. The single force of heat or steam introduced to raise the hammer has to be stronger than gravity *plus* the friction; therefore, it overcomes the lesser force, and raises the hammer until the steam is permitted to escape from under the piston, when it thus sets the hammer free to fall, unimpeded by gravitation; or the falling hammer force may be increased by applying extra steam-force on the upper side of the piston. In such a case gravity and steam act in unison as if they were a single force, by thus uniting their force and increasing the velocity of descent, both are acting in the same direction.

Motion, in a straight line, however, is not so convenient a condition for the greater number of man's mechanical purposes as the condition of circular motion, which is so generally employed. To produce circular motion, two distinct forces are required which are not in the same direction; this may be explained by the pendulum before us. Gravity would pull in a straight line if the string did not interfere, but its presence constitutes a second force which confines the ball to a centre, and so compels it to move in a circle. Thus all circular motion is made up of these two forces, the one moving it in a straight line, the other restraining it to a centre; and if the latter is overcome, as in cutting the string, or in the breaking of the fly-wheel of a steam-engine, it then obeys the natural law by flying off at a tangent, like a stone from a sling, and in a straight line but for the interference of gravitation.

In the varied operations of applied mechanics, an immense number of different kinds of motion are necessary; yet the universal experience of mankind seems to concur in the selection of circular motion as the preferable and most convenient for man to deal with and control, to receive, to store up, and convey force in motion; and although it may seem to be evident and natural to us now, still it may have taken man thousands of years to find it out, and when he did find it out, it was one of the grandest mechanical discoveries which he has ever made, because it fits in so conveniently with the nature of things existing in the world.

Before proceeding to the consideration of natural power, as applied to produce motion, there are a few elementary matters which had better be understood in order to avoid explanation afterwards. In the application of natural force to produce motion, it is necessary to know its amount or quantity. All mechanical power or force of any kind, when considered as an agent to produce motion or to accomplish some performance of mechanical duty of whatever nature, is technically called "work;" such "work" is reckoned by certain units, made up of matter and motion. A single unit of work is 1lb. of weight, or pressure, or force, raised or exerted in any direction, through the space of one foot; thus there are two elements, force and space, passed through. The plumb-ball before us weighs 1 lb. If it is lifted through the space of one foot, then one unit of work has been performed. If it is raised through 100 feet, then 100 units of work or force are necessary; or 100 lbs. through one foot would equal 100 units; or 10 lbs. through ten feet would equal 100 units; the weight, or force, or pressure in pounds, multiplied by the distance or number of feet raised or exerted through, is equal to the units of mechanical work. This simple method of reckoning force, or power, or "work," is employed in every kind of mechanical operation, as every force or pressure can be expressed in pounds, and any nature of resistance overcome, such as water rising or falling, the motion of a piston and railway train moved, or anything else done, of whatever nature, all are easily expressed in pounds and feet; so multiplying the pounds of pressure exerted by the space in feet exerted over, gives the units of mechanical work required or performed.

In dealing with large quantities of mechanical force or power, it is often, indeed generally found convenient to use a larger unit, say a horse-power or a man's power. The larger unit which is now agreed to is the measure of a horse's work, which is about 33,000 units or foot-pounds, as performed in one minute of time; and a man's power is usually considered as about one-tenth of the above, or equal to 3,300 units or foot-pounds performed per minute. By means of these units, together with the time addition, every kind of ordinary calculation respecting mechanical work done, or power required, is thereby rendered so simple that a boy may be made to understand the subject without any trouble.

A man working ten hours a day is capable of exerting 15 lbs. constant pressure on a crane handle, at the rate of 220 feet per minute, which is equal to 3,300 units, or the tenth of a horse power; by doing more than this he loses weight. In the case of a horse which is capable of pulling with a force of 150 lbs. at the rate of 220 feet in a minute, the force is equal to 33,000 units, or in other words, a "horse-power," which is about the average of what an ordinary horse can continue to do.

The average pressure of the wind exerted upon the sails of the windmill may be reduced to pounds, this force moving the sails at a certain rate per minute; the average pressure multiplied by the distance travelled in that time, and divided by one horse-power, namely, 33,000, will give the strength of the windmill in horse-power, but including friction and other hindrances. In the same way a certain weight of water expressed in pounds falling through a certain distance in feet, as performed per minute, these multiplied and then divided by 33,000, will give the nominal power in horses, or the average pressure exerted on the piston of a steam engine when moving through a certain number of feet in a minute, divided by 33,000 units, gives the power of the engine in round numbers; but the result of all such mechanical calculations does not give the actual or useful work which may be derived from those weights or pressures in pounds multiplied by the number of feet passed over, it only indicates the natural power at disposal, because anything that man does in applied mechanics is imperfect, more or less. The full advantage of the wind or water, or the steam, is not entirely secured in passing; then friction and many other sources of loss step in to still further reduce the available remainder, but the full measure of the force to be applied, or the work required to be done, is not depending on men. This depends entirely on nature. The amount of work secured, or lost, or wasted, depends on our arrangements, and hence it is that one man's imperfect arranging may and does constantly waste more force or power than another man's. For instance, to take the simple case of a water-wheel, to which I shall have to refer again, if the power is taken from the opposite side to that upon which the water is admitted, the friction upon the axle will be the weight of the water-wheel added to twice the water-weight or pressure. If, on the other hand, the more skilful engineer takes the power from the same side on which the water is admitted, then the friction remaining is only that which is due to the weight of the wheel; thus it is in everything relating to mechanism, manifested in thousands of different ways, but the majority of mankind do not sufficiently appreciate or discriminate between the two. Notwithstanding the increased knowledge of mechanical principles, there is still remaining a vast amount of misconception in regard to power; and, in looking back to the early days of applied mechanics, still more numerous were the popular errors existing in regard to power and motion. It was supposed that the force or power could actually be increased, in other words, created, by combinations of wheels and pinions in machinery, or that a regulating fly-wheel, by some means or other, really augmented the entire effect of the force, and such delusions still linger, to some extent, even in our own day, although we now begin to see the good result which is derived from the clearer light which is breaking through the past haze of ignorance.

A striking example of recent times was afforded, when Mr. Fairbairn first conveyed the motion of a steam-engine direct from the periphery of the fly-wheel. Before his time, it was invariably taken from a point nearer the axle, under the notion or belief that a greater ultimate effect could thereby be exerted, and the innovation made by Mr. Fairbairn was considered by the greater number of mankind as wrong in principle, forgetful of the well-known law that a given quantity of force or power could be expended in any condition, either as slow motion or quick motion, on the simple principle of the lever; that a small weight on the long end of the arm is equal to the heavy weight on the short end; that 10 lbs. at a distance of ten feet is equal to 100 lbs. at one foot; both are expressed by 100, both are in equilibrium, and, if motion is given, one has ten times the velocity of the other; both are the same as regards mechanical work, and the office of the engineer is to use the force or motion in any condition which best suits the immediate purpose; and he shows his ingenuity by its expenditure in actual useful work with the least loss by friction, not by the introduction of complicated and unnecessary moving parts.

A quantity of mechanical force in motion, equal to 100 horses' power, may be distributed over a cotton-mill. In this distribution, possibly 25 per cent. is spent before leaving the engine-room; and in friction, a large portion is spent in giving motion to the intermediate mechanism by which it is made to ramify to the various working points of beating, scutching, spreading, carding, drawing, roving, spinning, reeling, weaving, washing, pressing, and so forth; and the remainder only is the useful work that really cards, spins, and weaves the cotton into cloth; but these items, all united, make up the total 100 horses' power at disposal. But the whole of the 100 horses' power could be expended under any other conditions; it might be conveyed through a small endless cord, providing it were driven at a sufficiently high velocity, say 50 miles per hour, as in the telodynamic cord of M. Hirn, to which I shall again refer; or the 100 horses' power might be expended in simply drawing a single chain cable at a proportionately slower speed, and pulling with a corresponding greater force. If the one moves 1,000 times faster than the other, it can only exert the 1,000th part of the force, or it may be expended in any intermediate condition; but whichever way it is employed, it always comes to the same thing, namely, so many units of work, 3,300,000 performed in a minute, or equal to 100 horses' power, including friction and waste.

The using of natural force to perform work, although more prominent in our day, is not a new subject. Man's first efforts in the application of natural power for the purpose of assisting in the performance of the drudgery of his daily life, lie far beyond the reach of history or even tradition. It was an old art long before "Romulus or Remus had been suckled," even far beyond the time when the Egyptian Pyramids were erected; those grand works, the Pyramids, were not made by the "prentice hand" of man. Its introduction took place a long way farther back, away up in our own old fatherland, the home of the Aryan race, somewhere in Central or Western Asia, and it existed long before the Aryan swarms were sent off to people India, Persia, Greece, and Rome, and the whole of Europe. It is interesting to read that the words relating to peace and industry, to the domestic animals, to the weaving of cloth, and the working of metals, common in all these nations, have the *same root;* but that the words relating to war were afterwards originated separately by the several branches, after the great Aryan family had been broken up, showing that the arts of industry had been long established, or the nomenclature could not have been so firmly rooted in the whole stock as to be retained by the several colonies, when they, one by one, found a resting-place in other lands. Beyond such ethnological evidence as may be derived from language, there is no trace nor tradition bearing on the time when nature's power was first turned to account by man.

It may reasonably be inferred that man had long been familiar with mechanical art, and with the use of his own muscular strength in various ways, and had even learned to train animals to assist him in the drudgery of his work, before he was able to apply the mechanical powers of the lever, or the wheel-and-axle and the screw, and a long time must have elapsed before the ingenious millwrights of Persia had the mechanical knowledge to construct the interesting water-raising mechanism which are still used for watering the gardens of that sunny land.

As compared with those early days, we seem to come down almost to modern times when we mention the great and honoured names of Euclid and Archimedes, although they lived centuries before the Christian era. Now, we find mathematics, mechanics, and especially geometry, greatly advanced, and even applied mechanics in no mean condition. Some of the mechanical powers were clearly understood and reasoned upon. Machinery for raising water was constructed on various arrangements, and Hero, of Alexandria, shortly after *invented* his steam-engine, and applied an air vessel to produce a continuous stream for his fountain apparatus. Still, with all this knowledge and experience, it was yet a long time before we find water-power set to work to turn a mill for grinding corn; for, simple as such a thing may appear to us now, man had to go through centuries of experience, with apparatus still more simple before the human mind could clearly realise the mechanism that would enable falling or running water to give continuous motion, and thus allow the natural power to release the two women from the hard work of "grinding at the mill;" and it was not until the lapse of seven centuries that the windmill was invented, and, great as may be the contrast between the engineering of those times and the present day, still we have every reason to suppose that it may not be so great as the contrast between our present mechanical arrangements and those of some distant and future generation, as far as regards the application of science to make the best of the natural power which is contained in the world.

We are now to consider a little more closely the application of natural power by the applied mechanics of modern times.

It is only of late years that the heat of the sun has been recognised, so far as we are concerned, as the only source of natural power in the world, with the one exception, perhaps, of the great tidal wave, as pointed out by Mr. Mallet. At the present time this great subject is occupying the closest attention of the foremost thinkers, and the matter has already been so well investigated that it is now agreed upon by all that heat and force are convertible terms, and that either may be converted into or derived from the other; to know this as a fact is a great step forward in the march of mechanics.

The invaluable experiments of Dr. Joule and others show most conclusively the exact relation which exists between them, namely, that the amount of heat required to raise one pound of water one degree of temperature, as shown by Fahrenheit's thermometer, is exactly equal to the mechanical work of raising 772 lbs. one foot, or one pound 772 feet; in other words, 772 units of work, or 772 pounds-foot; that one pound falling through 772 feet, if suddenly stopped in its course, such as when a cannon ball strikes an armour plate, the amount of heat developed amongst its particles, if all collected, will be sufficient to raise a pound of water one degree.

Such precise knowledge as this affords is about to work great changes in all our mechanical arrangements for converting heat into motive power. From this definite data the engineer has a reliable standard wherewith to compare the results which he manages to obtain from the expenditure of a given quantity of fuel or heat, and instead of the feeling of self-satisfaction which has hitherto existed in regard to the amount of real work done by our steam-engines, there is now amongst engineers a growing sense of extreme dissatisfaction. It was a surprise when we came to learn that not one-tenth of the actual heat to be obtained from the fuel is turned to good account in the exertion of the mechanical force to do actual work, in raising water, or cutting iron, or weaving cloth; that fully-nine-tenths is lost in various ways, between the development in the furnace and the point of action in the engine-room. This is a matter which concerns our most vital calculations, and the feeling of uneasiness which it has created is immensely to be preferred to the opposite condition of self-satisfaction in which the world has hitherto been reposing.

Until recently (and even now for convenience) such machines as windmills, water-wheels, and steam-engines, were called "prime movers." It only shows the rapid change which is taking place, that such a term could not be given now. The possibility of such an expressive name being given to the mere mechanism, implies views which could only have originated at a time when men were narrowly restricted in their ideas of the wonderful system of nature. To realize freely and fully that heat and force are convertible, is the great modern task set before our young students, and calls for fresh thought and closer study, so that by the well-directed thinking of many minds, there may be less waste of the natural power than now exists with our present imperfect arrangements, vastly superior as they are, when compared with the mechanism of 150 years ago.

It is scarcely necessary to refer to the force or power of man or animals, as derived from the heat of the sun which shines alike upon all, and universally recognised as the agent, under a Higher Power, which causeth "the pastures to be clothed with flocks," and "the valleys to be covered over with corn, providing food for man and beast." Nor is it necessary to refer to the sun-agency in connection with the mechanical power which is derived from the wind in motion, in propelling ships and turning windmills, as the motion of the atmosphere in the wonderful economy of the universe is entirely due to the heat of the sun. The air that is immediately resting on the warmer part of the earth's surface is thereby heated, expanded, and rendered lighter than the cold air which is above and more distant; consequently the heated air rises in virtue of its lightness in the same manner and on the same principle that water circulates in a steam boiler, or that hot air rises in a chimney. Thus, the warm air rises to a higher stratum in the atmosphere, and a circulation of air is set up from the colder regions to supply the void, and these currents of air, every foot weighing an ounce and a quarter, are made to perform a little work in passing, by expending their force upon the ship's sails, or the vanes of the windmill; and strange although it may appear at first sight, it is thus the same prime mover, namely, the sun, that forces the sailing ships along as that which propels the steam vessel, the only difference being that, in the case of the sailing ship, it is the effect of the sun's heat as performed from day to day, whereas in the steam vessel it is the effect of the sun's heat, emanating, probably, millions of years ago, and treasured up in our coal-fields, in a concentrated form, for the benefit of future ages. What a wonderful little world we live in, and still more wonderful is the grand universe of which it forms a fractional part.

Even the circulation of water upon the earth's surface is also due and clearly traceable to the heat of the sun. There is no substance on our little earth which is so generally diffused as the precious liquid water. There is no other substance in nature that has so many important and such varied offices to perform, in every condition of existence. Now, it is a solid frozen mass; with a little heat, it gradually becomes the liquid water; and with a little more heat, it assumes the expanded aeriform state of steam. Now it is covering the ocean as a liquid, upon the surface of which the heat of the radiant sun is constantly at work, pumping the water upwards into the condition of clouds of vapour, all rising from the sea, and lakes, and rivers, or other bodies of water, in ceaseless evaporation. For a time it is suspended as an invisible vapour in the atmosphere; by-and-bye, from coming into collision with nature's surface condensers, the chilling hill-tops or other cooling influences, it is then condensed into fogs and mists, and drizzly rain; then falling by gravity upon the earth-surface, gravitation still bringing it downwards by channel and rill, and burn and beck, by lake and loch, and river, never resting, but still downwards, until it finds its way back to the ocean, from whence it came. Again, in time it is raised up once more by the sun's action to repeat its varied course of perpetual motion, round and round, never ending, and thus supplying the wants of plants and animals in its circulation, and always again restored to its native ocean for a holiday, to be rested, sweetened, and purified for further duty.

It is from this never-failing action of the sun that the water-power of applied mechanics is derived; the sun raises the water, gravitation simply carries it back again. It has been computed that 13,000 cubic miles of water is evaporated every year, the same quantity necessarily falling down again. Man now steps in, and by his ingenuity arrests some of the passing water in its downward course, and so takes advantage of a small portion of its force or power to give motion to his water-wheels, engines, and turbines, and then, by some simple mechanism which he has devised, controls the force so as to make it perform the drudgery of grinding the corn for his daily bread, or even to spin and weave the materials for his clothing, and many such like purposes. But no power whatever is derived from the water-wheel or the turbine, or anything that man does; it all comes from the sun which first raises the water, thus giving gravitation the opportunity to carry it downwards, and man merely presents a wheel for the gravity or weight of the water to turn it round, by the catching of a small portion of the natural force in passing along its course.

From the long period which has elapsed since water was first employed to give motion to machinery, and owing to the subject having passed through the hands of so many of our modern great men, from the time of Smeaton down to that of Fairbairn and Fourneyron, the subject of water-wheels has been almost exhausted. Water-wheels or turbines, when considered as machines contrived to take advantage of the natural power which is applied to them, are much more perfect in their way than the more recondite steam-engine; still, even with the best of the water-wheel or turbine class of machines, they scarcely absorb 75 per cent. of the power at our disposal, that is to say, more than 25 per cent. is wasted or lost in its passage through the apparatus.

A cubic foot of water weighs 1,000 ounces, or 62½ lbs.; hence, by ascertaining the number of feet delivered per minute, this weight multiplied by the height in feet through which it falls, and divided by 33,000 units (which is a horse-power nominally) would indicate the actual power; but as will be seen by a close examination of the section of a water-wheel, even of the most modern and improved construction, many sources of loss and leakage will still be apparent, even after everything has been done to practically make the best of it, and to close up all waste of effect, so far as present knowledge will permit.

To make the most of water-power, the modern practice is, to dam up the head-water disposable until it is almost in a state of rest, so as to raise it up to the highest possible level at the point where it is to enter on the water-wheel, and thus to use only the cream of the water, in order, if possible, to make every inch of the water-fall available, the height of fall being equally as important as the quantity or weight. These two conditions alone determine the actual power; the adaptation and skilful construction of the machine determine the amount of effective power which is made available.

Theoretically, the impulse of running water as derived from gravity, ought to afford the same per-centage of duty as by taking advantage of the gravity in a more direct manner; but in this country, engineers generally have, of late years, settled down to follow Mr. Fairbairn in the construction of what are termed breast-wheels, similar to that shown in the diagram on the wall. In France, the other principle is more frequently preferred, the practical effect of both is nearly alike.

When a machine has been a long time in use, and passed through the minds of many, man gradually closes up the sources of waste. This refining process has gone on for a long time with water-wheels, until at length certain general rules are agreed to as affording the best result. The size of a water-wheel may be from that of a donkey-power to several hundred horses, that being determined entirely by the situation, the quantity of water available, and the height of water-fall; but the speed at which a gravity-wheel yields the largest percentage of duty is determined by Newton's great law of attraction, as determining the rate of falling bodies. The water, if left to itself, would fall at the rate of all falling bodies, or about 16 feet per second; yet, if it were allowed to do so on a water-wheel, evidently it could do no work besides; but the retardation of the wheel thus interrupts the descent to a much slower pace.

It has been found that the best result is obtained by allowing the outside of the wheel to move at about three and a half to four feet per *second*, *that* is, about the velocity of water when falling about seven or eight inches; hence the water falling over the sluice upon the buckets of the wheel, a distance of seven or eight inches, gives little or no shock. This rate of motion gives a speed to the periphery of the wheel of 210 feet per minute, or thereabout, whether large or small.

Another nice point which has been well considered in connection with modern water-wheels, so as to make the most of the water-fall, is to lower the sluice in order to admit the water, instead of raising it, as in older descriptions of water-wheel, for the water to pass under. By this simple means an increase of effect equal to the depth of the sluice is added to the fall, and thus, so to speak, the cream of the water only falls over the upper edge as it descends, and hence the most of the height of the water-fall is made to perform work.

A water-wheel for cotton-spinning, like a clock, has to work at a uniform speed; and the same means, namely, a modification of pendulum, is employed in both cases. To the water-wheel a species of revolving pendulum, termed a governor, is employed. All are familiar with the action of the same governor in the steam-engine. In that machine its office is to open and close a so-called throttle-valve, which regulates the admission of the steam according to the work or rate of motion of the engine; but the office of the water-wheel governor is of a more refined and dignified nature; it is more a consulting governor, to give advice when wanted, rather than a governor to really perform the hard work of moderating the water supply, as the engine governor does the steam. The sluice of a large water-wheel is an immense iron shutter, which, although counterbalanced by a weight, is still a ponderous apparatus to adjust, and cause to slide up and down, as the varying water supply, or even the changing work to be done in the factory, may require.

This laborious duty of moving the sluice is assigned to the water-wheel itself to perform; and the office of the governor is merely to suggest to the unreasoning-wheel which way to move its own sluice, so as to feed itself properly and regularly. This is accomplished by a very familiar combination of two bevil-wheels running loose upon a shaft, with a clutch between them, and working into a third, the third being the wheel that communicates with the sluice. Each of the two wheels, when giving motion, necessarily turn the third wheel in opposite directions, and as the governor rises or falls by change of velocity, it reminds the third wheel, by means of the clutch being made to slide or move either to the one bevil-wheel or to the other, in order that the proper wheel may have the motion which is suitable for the necessary movement; and during the periods when the required speed of the water-wheel is maintained both of the bevil-wheels are at rest, the governor being always sensitive, and on the alert to jog the one or the other.

With these explanations, and the assistance of the diagram on the wall, the leading features of the water-wheel will be understood. The curved plates (or buckets as they are termed) that receive the water, are arranged in such a manner as to allow the air to escape freely and without splashing the water, and are so formed as to enable them to retain hold of the water the longest possible period. During its descent, the wheel revolves in close contact with a corresponding arc or curve, and is enclosed by segments at the ends of the buckets, in order to prevent the water from escaping; *but, as will* be seen by an inspection of the diagram, a considerable portion of the water is still unavoidably wasted, by resting on the surface of the arc and otherwise. From these causes, and from the prejudicial effect of the water leaving the wheel with too much velocity, and from the wheel having to rise out of the tail-water, together with the friction of the wheel upon its bearings and other resistances, not far from 35 per cent. of the power is thus wasted, or at least not available for duty, in the greater number even of the better class of water-wheels.

Another great modern improvement in connection with water-wheel mechanism, consists in the manner of conveying the motive-power from the water-wheel to the factory. In former times, the motion was taken from the axle, consequently the water-wheel had to be sufficiently strong and heavy to bear the transmission of the power; but in modern wheels, the axle and arms have merely to keep the great outer ring of the wheel that carries the buckets in its proper place, thus giving a light skeleton wheel, with the waste from friction reduced in proportion.

It will also be observed that the toothed-gear for imparting the motion and power is upon the ring, and thus the motion is taken off the wheel at the point where the water is most effective; hence the weight of the water comes almost direct upon the spur-wheel to be driven, and, comparatively, scarcely any strain comes upon the water-wheel as a structure. In the second place, it absorbs the weight of water in a direct manner, and thus removes the double friction that would otherwise be entailed, that is to say, the conditions would be entirely reversed if the motion were conveyed from the other side of the water-wheel. And a third great advantage of this arrangement arises from the high speed which is at once given to the driving-shaft, thus avoiding the necessity for intermediate gearing that would otherwise be required if the power was taken from a smaller diameter. From this, also, two other important considerations follow, first, a reduction of the first cost of gearing; and secondly, a diminished friction, as the strength required and the weight of shafting diminish with the increase of the velocity.

Although the venerable water-wheel has been the most frequently employed in this country, still it is not by any means the only machine for taking advantage of water-power.

For situations where the quantity of water is limited, but where the fall is considerable, water-pressure engines, with cylinders and pistons like steam-engines, are sometimes resorted to, and yield a per-centage of duty fully equal to the water-wheel, but they are more expensive and complicated, and only used for very high falls.

But there is another class of water-mill now coming into extensive use, called turbines; they are more simple than the water-engines, and less expensive than water-wheels. Turbines are made in many different ways, but in almost all the power is derived from the confined fluid pressure of water rather than from the mere weight of falling water, the pressure in the turbine, however, being due to the gravity resulting from the vertical height. On this account, the turbine is more accommodating and better adapted than the water-wheel for any varying range or height of water-fall, and may be used for 400 feet, or, with a slight modification, for a fall of only a few feet, the power being in proportion to the height of fall and quantity of water passing through the machine in a given time. This is a great recommendation in their favour for most practical purposes.

From careful experiments made with turbines, the percentage of duty is found to be slightly higher than with water-wheels, arising chiefly from their not being affected so much with tail or back-water, and likewise from their peculiar fitness for running at a high speed. It seems probable that, in the engineering of the future, they will ultimately supersede the water-wheel, except for special situations.

The diagrams on the wall show that the turbine is made on many different plans of arrangement, so that it is impossible to describe them in this lecture. As a rule, the rush or flow of water under pressure is guided in a certain direction, and thus made to impinge on the curved vanes of a kind of small water-wheel, as shown on the diagram. Frequently they are arranged as a small water-wheel with a vertical axis, the water passing either from the inside through the buckets, or from the outside to the interior; and in those of the best construction the turbine is balanced, that is to say, the machine is so contrived that the pressure of the water is equal in both directions, so that from being in a state of equilibrium, the friction which would otherwise exist is thereby avoided, thus increasing the effective duty.

A disadvantage which sometimes accompanies the possession of water-power arises from circumstances, in which it may not be in the best situation for being turned to practical account, such as in driving a factory, or otherwise, as may be desired. To overcome this difficulty canals are most frequently resorted to, in order to convey the body of water to the spot where the power is to be used, which is obviously both cumbrous and expensive. Within the last few years, M. Hirn has contrived an exceedingly clever mechanical arrangement, by means of which the power, spirit, or essence of the water, rather than the gross weight, is transmitted for several miles by means of a small steel wire rope, which is driven at a correspondingly high velocity; this is on the well-known mechanical principle that a small weight or pressure at a high velocity may be equal to a very great weight or pressure at a proportionately slow rate of motion. He erects a water-wheel or turbine in the most convenient place beside the water-fall, and, by means of a toothed-wheel work, gives motion to a large driving-pulley some ten or twelve feet in diameter, which is whirled up to a speed of 6,000 feet per minute, and over this pulley he passes the endless cord, which transmits the motion to a similar pulley on the other side of a valley, perhaps some four or five miles distant, the cord being supported at intervals by other suitable pulleys, in order to prevent it from touching the ground. In this way a force equal to 100 horses is readily conveyed for a distance of five miles, and is said to yield fully 75 per cent. of duty. In the earlier experiments considerable difficulty was experienced, chiefly arising from the repeated fractures of the small wire rope or cord, owing to its extreme velocity, of some 50 miles an hour. This deterioration of the cord was found to arise from its having to work over the groove of hard pulleys, but, by providing a cushion of gutta percha which lines the bottom and sides of the grooves of the pulleys, the difficulty has been entirely surmounted; and by means of this admirable combination the great force of the water-fall, by being thus changed into the condition of a small force at a high speed, is conveniently dealt with, and the living principle of the natural water-power is thus transmitted without incurring the expense of transferring the dead weight of water over the intervening country, which in many cases would be impossible.

The great success which has attended this invention of M. Hirn will soon lead to a further application of the principle in many different ways. Indeed, during the last few months, an apparatus of an analogous character, but differing in principle, being arranged with a thicker rope and slower motion, has been established near Leicester, for the conveyance of stones. It consists of an endless rope passing over pullies on a series of poles, for a distance of three miles; the stones are contained in boxes suspended from the rope, and are delivered at the rate of ten tons per hour; the whole apparatus being worked by a small portable steam-engine, and it is said to be eminently successful, and satisfactory in its working in every respect; doubtless other applications of this mode of conveyance will yet be developed, as determined by circumstances.

The knowledge of the simple fact which has been developed by M. Hirn, that any reasonable amount of mechanical force or power may be transmitted through a small cord, when it is driven at a sufficiently high velocity, will yet work many changes in the future arrangements of the world, but which cannot be foreseen nor imagined at the present time. The study of each recurring century will lay bare the hidden stores that are laid up in nature.

We now come to consider the class of mechanical power engines which act by the effect of heat in a more direct manner than in those for wind and water power. These heat-engines admit of endless variety of construction, and already assume many forms, and employ different agencies for the heat to act upon, such as steam, air, or even gas, but all depend for their effect on the natural expansion of volume by heat, and the natural contraction of volume by its withdrawal. Up to the present time, for practical purposes at least, every one of these heat-engines depends for its efficacy on the reproduction of the heat of the sun, either past or present, especially the former, which has been treasured up for us, stowed away in the vast coal-cellars of the earth, probably for millions of years before our time.

George Stephenson generally gets the credit for having been the first to recognise this natural fact, but the same idea was thrown out in one of the early editions of "Herschel's Astronomy." Such a truthful statement was calculated to take the mind by surprise, as mankind were scarcely prepared to believe that light and heat, as absorbed by the plants of far-off ages, had been thus condensed, and now made to give back the light and heat, and that these plants are actually liberating the same carbon and the same hydrogen which was then absorbed, and that tbe old carbon and hydrogen are now being set to work in our factories, being the prime agent affording the motive power to give motion to the screws and paddles for the various means of conveyance, as required by man, both in ships and railways.

With wind and water power, as formerly stated, it is the effect due to the sun's work of the present time that we are using, and which will last "so long as the sun and moon endureth;" but with the natural power of the sun in the olden time, in the condition of coal, it is a limited quantity only which is placed at our disposal; hence, as a generation, we are not warranted in wasting the rich patrimony which, as a nation, we have so bountifully inherited; and it is the special province of the engineer, like a good steward, so to contrive his mechanism as to make the best of our mineral resources without either waste or extravagance, so far as present knowledge will enable him. In the past, and even now to some extent, we have been and are by far too apt to congratulate ourselves in regard to the perfection of our heat-engines, and especially the steam-engine, yet the sad fact remains that only a small portion of the effect of the heat is turned into useful work. As compared with Hero's steam-engine of 2,000 years ago, or Savory's steam-engine of 200 years ago, or even of Newcomen's steam-engine of 100 years, the duty is increased nearly ten-fold, but, as compared with the standard of Dr. Joule, of 772 foot-pounds to be derived from the small quantity of heat required to raise one pound of water one degree, we are still in a woful condition, yet not without good reason to hope and believe that many other Watts and Stephensons will arise during the next 2,000 years to carry the work forward.

In the case of the steam-engine as now existing, probably one-half is wasted in the furnace, the flues, the boiler, and chimney. Heat is wasted in the engine, and all heat escaping as warm water from the condenser, or as steam from the chimney of the locomotive; even after a small portion only of the heat of the coal in the furnace has become converted into real mechanical force, in order to give motion, say to a factory, of this small remainder a large fraction is wasted in friction, sometimes to such an extent as to increase the temperature and become sensible to the touch. All motion involves the waste of heat, and all heat not converted into the real work to be accomplished is heat lost. How careful, then, ought we to be in the perfecting, lightening, and simplifying of our mechanical constructions, and what a boundless field opens up to the students of the future. It is only such considerations as these that will serve to stir us up to an endeavour for improving our machinery to the very utmost, and, for its own sake, we must become more refined in our ideas of construction, and more parsimonious of power, and so economise in every direction; to have as few moving parts as may be practicable, and those as light and correctly fitted as possible, as every unnecessary squeeze, or rub, or friction of any description involves a waste of the precious power which has been so carefully laid up for man to use, but certainly not to abuse in the manner which we constantly see, and students will find it a healthy exercise to study applied mechanics from this point of view.

The nearest approach to perfection in the primary use of heat has been made with hot-air engines, in which the cold air, passing inwards to the engine, takes up the heat of the hot air in passing outwards, after having done its elastic work; but such engines hitherto have chiefly failed through practical difficulties, which may, and no doubt will yet be overcome, especially from the circumstance that so many ardent minds are now fastened on to this subject, and all are impressed with the waste of existing arrangements; indeed the subject is ripe for the earnest and continued study of our young engineer; and man's work will not be done, even with the well-worn steam-engine until a much larger percentage of duty is derived from a pound of coal than is now obtained.

The highest duty yet performed by a steam-engine, so far as I have been able to verify, is a small fraction under 1,000,000 lb. raised through one foot by a single pound of coal, and some are reported even higher, but immense as this may seem, it is scarcely the tenth of what the pound of coal is equal to, provided that it be wholly converted into useful effect. Possibly, in the very nature of practical things, man may never be able to reach even half-way to the full measure of perfection; still, if all our students strive to do their utmost with every detail (for in that alone, with existing principles, lies hope), much will yet be effected; and, reasoning from the condition of the Newcomen engine when first put into Watt's hands, and what it has since become by Watt, Stephenson, Fairbairn, Penn, Napier, Hick, and many others, and from the high standard of mechanical construction which may now be obtained by modern tools, and from the fresh knowledge of scientific principles throwing light upon every subject, more especially in regard to the wonderful phenomena of heat by the investigations of such men as Professor Tyndall, there is good reason to hope that many points of leakage of force which now exist in the steam-engine will be closed up one by one, although some of them, so far as we can see at present, may now be deemed impossible, when judged by the experience of this period in the history of applied mechanics.

In this commercial age everything, including natural power, narrows itself down into a pounds-shillings-and-pence question, and hence the most successful engineering, judged by modern notions, is that which will give the best return in useful work for a given expenditure, considered not only in reference to first cost for the mechanical apparatus itself, but of that likewise taken into account along with the future working cost for fuel and other expenses, and without reckoning the power required to work the engine itself as part of the work. If some such mode of buying heat power were introduced, even approximately, so as to put all constructors of heat-engines upon their mettle in this direction, it would soon lead to a great economy in many important respects that now pass unheeded.

The system of selling or buying steam-engines at so much per nominal horse-power is so very far wrong that probably few will now be found to defend the practice. There can be no equitable transaction or fair competition until that which is bought and sold is reduced to work performed in foot-pounds, or some better or more convenient unit, if any such can be devised; some definite quantity for a given expenditure, with the cost of fuel and expenses of every nature being taken into the calculation.

In considering the subject of heat-power, the actual and effective heat to be developed from the coal is one of the chief questions. Heat itself is the only grand agent; the steam, air, or gas are the mere subordinate instruments for transmitting the effects of heat to pistons or other mechanism. The subject therefore divides itself into three distinct parts; first, how are we to obtain the whole heat from the fuel; secondly, having obtained the whole heat, how are we turn it to the best practical account as a producer of steam or heated air; and then, thirdly, comes the consideration of the mechanism to be employed for converting the force of the heat-agents, steam or air, into mechanical power.

We may regard a furnace under a steam boiler as a chemical laboratory on a large scale, in which the object is to mix coal and atmospheric air in the best proportion, so that the carbon of the coal shall be converted into carbonic acid gas, and the hydrogen into water, and that the changes shall be effected in such a manner as will develop the full heat of the fuel, and that as much as possible of this heat shall be communicated to the water in the surrounding boiler, and as little as possible shall be wasted either by radiation or conduction, or by cooling through any cause, or by passing up the chimney, or otherwise.

When all this is done by the chemist with the utmost care, we read that a pound of good coal in his hands will evaporate 14 lbs. of water, but in our practice, even with the very best arrangements yet devised, 12 lbs. is rarely if ever reached, even 10 lbs. is extremely exceptional, 8 lbs. is reckoned very passable duty, and down even to 4 lbs. is not uncommon. A great part of this waste is mostly due to small causes, many of which could, in a great measure, be obviated if we had more thrifty notions.

The attainment of perfect combustion is as much a matter of oxygen or atmospheric air supply as of fuel. The air consists of one of oxygen with four of nitrogen; the main constituents of ordinary coal are about 80 per cent. of carbon, and 5½ per cent. of hydrogen, in varying proportions according to the sort, the remainder consisting of oxygen, ashes, and other matter. In coal the carbon and hydrogen are both united and in the solid state, but each of these constituents has its own way of entering into combustion, and neither of these will commence burning until they are separate, and then they begin to burn each in their own order, and in that way only. This version of the process is quite different to the usual notion. It is generally supposed that when coals are thrown into a fire they begin to burn all over as a matter of course; but this is not the natural law that we have to comply with in the burning of coal, the breaking of which law involves not only waste of heat, but causes smoke as well.

The combustion process in a furnace is well explained by that which takes place in gas-making, the chief, indeed, the only difference that exists being this, that in the furnace the gas is consumed as fast as it is made, while the gas-maker stores up the carburetted hydrogen gas in holders, after passing it through lime in order to purify it from sulphur and ammonia; then he sends it out to the public to be used for light and heat. The gas, when it reaches the consumer, if it is supplied with its proper quantity of air, namely, ten times its own volume, will burn brightly without smoke, and give up all its light and heat. The residue of coke, which is left in the retort of the gas-maker after the gas has been expelled, is then withdrawn to be otherwise used as fuel, whereas the engineer consumes it in the furnace as the principal source of heat.

Now, the first duty to be performed by the engineer in burning a ton of coal in a furnace is shown by the gas-making process. The ton of coal gives off from nine to ten thousand cubic feet of gas, and requires about 100,000 cubic feet of air to produce perfect combustion. In one important respect the two processes are unlike, as, in a furnace, the fuel may be, and generally is, in all stages of combustion, but every individual particle of the coal, large or small, burns in one way only. The hydrogen has first to part company from the carbon before it combines with the oxygen, and the carbon portion does not commence to burn until the whole of the hydrogen has gone off, and if the engineer has done his duty in giving the gas which he produces the ten volumes of air which it requires, it will then burn as brightly as the gas of the gas-maker, providing the temperature is sufficient for its ignition. When the hydrogen has quite gone off, then the carbon commences to burn, but not till then, and it will continue burning to the end, if a proper allowance of air is supplied.

On the other hand, it is not only necessary to give a sufficient supply of air both to the carburetted hydrogen and to the carbon as they severally need it, but it is almost equally bad in another direction to give too much, as any cold air passing through the furnace without taking its full share of the work is a robber of the heat produced by other air, besides damaging the boiler and producing smoke. Hence it is that the combustion of fuel will seem, and does really seem to many, to be a rather complicated matter, and a law difficult—almost impossible—to obey, but whether difficult or not, this is what the furnace has to do, and in nature there is no allowance made. There is the law, and our duty is simply to find it out and to obey it, and if we fail in any particular, either by excess or shortcoming of air, an £ s. d. fine will be inflicted as certainly as two and two make four, much more so than the fine which is inflicted by the magistrate for the nuisance of smoke.

Fortunately, however, it is not so difficult to comply with the natural law, if we only take the trouble. When coals are thrown upon a furnace, the first effect is to lower the temperature by the quantity of heat absorbed by the fuel in expelling the water. The next stage is separation and departure of the hydrogen, carrying along with it a portion of the vapour of carbon, and this will require its share of ten feet of air to every foot of gas, not vitiated air which has passed through the fire, but pure air containing two feet of oxygen, and some, indeed the whole, of this air must be supplied to the gas, either by the furnace-door, bridge, or sides, or in any other better way that can be devised, except through the fire-bars, and it must be given in a varying quantity to suit the ever-changing quantity of gas that may be evolved for the time being, which at first is gradually increasing, and then gradually diminishing.

The next demand for air is to supply the remaining carbon which is lying on the fire-grate, and the quantity of air necessary to be supplied through the fire-bars, for that constituent for a ton of coals is about 240,000 cubic feet; thus, with that required for the carburetted hydrogen, making altogether 340,000 cubic feet, and if the gas and the carbon cannot (from any cause) get their proper quantities of air to yield the necessary oxygen, then they are compelled to go without, and the full heat is not evolved, and it ends in smoke; or if there is too much cold air admitted, smoke will be the result, because it requires temperature as well as oxygen to give perfect combustion. The apparent difficulty of securing perfect combustion when a furnace is replenished by manual stoking, where the fuel is of necessity introduced in large quantities from time to time, has led to many ingenious attempts for supplying fuel by some mechanical arrangement which shall be constant, thus enabling the engineer to provide a certain measured quantity of air to meet the respective wants of the gas and the carbon. Of the more recent applications in this respect is the system of reducing the fuel to gas before it is introduced into the furnace, and, by another arrangement, the coal is reduced to a fine powder, which, with the proper allowance of air, are together wafted into the burning chamber, thus giving each atom of hydrogen and carbon the opportunity of selecting their partner of oxygen, and in an instant producing their full light and heat, and no doubt the furnaces of the future will be in this direction rather than on the present system.

If we had time to follow the heat which is thus developed in a furnace through the chimney, the boiler, the water, the steam, and the engine, an opportunity for wasting it would present itself at every turn. To take the case of the chimney in connection with Dr. Joule's equivalent of 772 lbs. raised one foot, by the heat required to raise a pound of water one degree. From a course of experiments which were made recently at Woolwich, it was found that the gases from an ordinary furnace may be drawn downwards through a tubular vessel containing cold water, and made to give up the whole of the heat in the gas to the cold water which entered at the bottom, and the amount of heat which was thus saved, was considerably beyond the theoretical value necessary to create the draft by mechanical means. This is a matter well deserving the attention of our young students, to devise convenient modes of adaptation to fit in with existing arrangements.

That the chimney is the cheapest or best mode of obtaining a draft of 340,000 cubic feet of air for the combustion of every ton of coal is exceedingly doubtful. This prodigious quantity of air, besides the immense volume of gas or steam from the fuel, weighing together about thirteen tons, and passing away at a temperature never under 300°, and generally considerably higher, even up to 500° or 750°, implies such a waste of natural power as is altogether unwarrantable, more especially as the coal mines of Great Britain are not inexhaustible, and the whole question opens up a tempting field for future investigation.

Although heat is the grand primary agent in all heat engines, still it requires to be employed in connection with some material substance. In the case of the steam-engine it is water, in air-engines it is the atmosphere; but so far, when practically considered, steam is found as yet to be the most convenient medium for conveying the power of heat to the piston of an engine, at least so far as the present systems of construction and mode of using materials have determined.

As regards the mechanism of the working steam-engine, we are on the eve of great changes. During the past few years new ideas have sprung up in regard to the pressure at which steam can be safely worked, and the speed at which a piston may be driven. The old notion of 220 feet per minute is now being abandoned, and engines are already working at a velocity of 800 feet. By this means the power of a given size of engine-mechanism is increased nearly fourfold, that is to say, a given pressure on the piston travelling nearly four times as fast as it used to do, like the telodynamic cord, will transmit mechanical work in proportion, of course requiring an increased volume of steam. But such increased velocity demands sounder and more refined workmanship, larger bearing surfaces, and every moving part as light as possible; and the mechanical world has to be gradually educated to a higher level, in order to make good the position already achieved.

Another modern feature is, the various attempts that are being made to economise steam when it reaches the engine. In past times, as a general rule, this most important point has not received sufficiently close attention; too much steam is lost in the passages; valves do not open and shut with the absolute precision which is necessary to produce the greatest effect; due advantage has not been taken of the expansive property of steam after it has entered the cylinder. The office of the governor has been confined to cutting off the supply when the engine went too fast, or to admit more steam when it went too slow. All this is being altered in the foremost class of engines; the steam passages are being shortened; several arrangements of value are being introduced whereby the steam is admitted at the precise moment, then closed again as promptly, and the time of closing, together with the degree of expansion to be given to the steam as depending on the work to be done for the moment, are determined by the governor at every stroke of the piston. The escape of the steam after doing its work is also being put upon a better footing; it is now arranged so that, at the precise moment of time, the way of exit is full open, and remains full open during the whole stroke, and then instantly closes.

Another fertile source for future economy lies in the direction of increased steam-pressure, and along with that an increased expansion in the cylinder of the engine. During the past hundred years it has gradually risen from a pressure about equal to the atmosphere or a little over, to that of 150 lbs. on the square inch, and no barrier has yet presented itself which would indicate a limit beyond the strength and goodness of the materials and the size of the apparatus; and, so far as can be seen at present, 500 lbs. per inch does not seem beyond the bounds of possibility. This, however, is a matter "which time will develop and bring to maturity, like the acorn in reference to the oak." Our present duty is to creep warily in dealing with such enormous pressures, when bottled-up in boilers as at present constructed.

Perhaps these several changes may not seem much in themselves, when individually considered, but collectively they are important, and all are in the right direction, and point still farther. Other nations also are equally active in the earnest endeavour to make their steam-engines more economical, especially France and America; possibly, the higher price of coal in those countries may have impelled them to a study of these points, in order to meet the commercial competition of the world; but, if we are not equally determined to improve our steam-engines, it would be throwing away our only advantage, namely, that of having cheaper fuel.

The simple statement that some modern engines are really performing four times as much work, in foot-pounds, from a pound of coal, as some other engines of inferior construction, requires no comment. The blame does not lie so much upon engineers as upon the purchasers and employers of engines, who are too often content with a rude and less costly engine, extravagant in fuel, compared to an engine of more refinement. Now, however, that attention is aroused and concentrated on increased economy, by Mr. Scott Russell and many others, there is no doubt but that we shall have our engines as good and as economical as any in the world; but if we do not, the blame will certainly lie at our own door, as, from the nature of steam, it will submit to any mode of treatment; it will follow a piston in a cylinder many times faster than any reciprocating piston made of existing materials will bear to be driven, or, in imagination, even the still higher velocity of some future revolving helical wheel, a modification after the plan of Hero of Alexandria, of 2,000 years ago.

To see a locomotive engine running past at a speed of 30 miles an hour, and to watch the motion of the engine-piston, it might appear as though the steam could not follow so rapidly and yet retain its full force. Such however, is the case, for although a single revolution of the driving-wheel upon the rail, passing the train over a space of 15 feet, involves the twice filling and emptying of each of the two cylinders with steam, or four cylinders full of steam altogether for one revolution of the engine, or 1,400 cylinders full of steam in the course of a mile; still the limit of the speed is not with the steam as a natural agency, but depends on the generative power of the boiler to supply the quantity, and on the sound construction of the reciprocating parts to sustain the velocity.

The great success which has attended the introduction of the railway system is due to the *action of the locomotive wheel* upon the smooth rail. At the commencement of this lecture, reference was made to the selection of circular motion as the most convenient for the requirements of man; there is no better illustration of its manifest advantage, than in its adaptation and fitness, as shown in the driving-wheel of a locomotive engine as it runs along upon the rail. At first we are scarcely willing to believe that its lower side is always in a state of rest upon the rail, that the wheel is an endless rolling fulcrum of a lever, continually advancing, but still at rest, with the centre of the wheel only moving at the velocity of the train, and with the upper side of the wheel advancing with twice the velocity through space, it being twice the distance from the centre of motion.

If time permitted, I would have referred to some of the different modes of dispensing or conveying mechanical work after it is realised, by gearing, by endless bands, by compressed air, by water pressure, by means of a vacuum, or otherwise; but enough has been said to show that the natural power of applied mechanics is a great field open for closer investigation, and one which, if followed up in earnest, will not go unrewarded.

We sometimes hear desponding remarks made in regard to the future of applied mechanics, but let no one assume that the field of discovery and invention has become narrowed in any degree, or that scarcely anything but the refuse of the past remains for our young men or for the men of the future. On the contrary, so many fresh ideas pour in upon us from day to day, that the prospect is continually widening, every new idea seems to form a clue to an endless chain of other ideas; and, as the tide of civilisation rolls along in its ever-advancing course, it gradually ameliorates the condition of our race, and will continue to do so until all the drudgery of work shall be done by machinery, leaving to man only to guide and to direct by his growing intelligence, thus in time removing the sting from the primeval doom; and it will be found, so long as any of nature's secret laws remain unexplored, that well-directed irrepressible thought will alight on new discoveries one after the other, and to the endless variation of mechanical combinations there is practically no limit.

Proceedings of Institutions.

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EXAMINATION PAPERS, 1869.

(*Continued from page 757.*)

The following are the Examination Papers set in the various subjects at the Final Examination held in April last:—

NAVIGATION AND NAUTICAL ASTRONOMY.

THREE HOURS ALLOWED.

Section I.

1. Define a side and an angle of a spherical triangle, and show that the greater angle is opposite to the greater side.

2. Define the polar triangle, and show that the angular points of the original triangle are the poles of the opposite sides of the polar triangle; and that an angle of the original triangle and a side of the polar triangle are supplementary.

3. Prove that in any spherical triangle the sines of the angles are proportional to the sines of the opposite sides, and assuming the expression for an angle in terms of the sides, that $\text{cot. } a.\ \text{sin. } b. = \text{cos. } b.\ \text{cos. } c. + \text{sin. C. cot. A.}$

Section II.

1. Write down the rules for the solution of a quadrantal triangle. Find an expression for the hour of sunrise on a given day in a given latitude.

2. Given two sides of a spherical triangle, and the angle opposite to one of them,—solve the triangle.

3. State and prove Napier's Analogies.

Section III.

1. A ship in latitude 37° 40′ N., longitude 3° 18′ W, sails due south 135 miles. Required the *compass course* and *latitude in*. Variation 23° W., deviation 3° 20′ W. leeway 1 point, wind W. b. N.

2. Required the compass course and distance from A to B.—

Lat. A 14° 18′ N. { Var. of compass 15° E. } Long. A 75° 28′ E.
Lat. B 12° 33′ N. Dev. 8° 14′ E. Long. B 94° 45′ E.

3. June 15, 1869, at noon, Lisbon, lat. 38° 42′ N., long. 9° 8′ W., bore by compass N.N.E. distant 25 miles. Ship's head N.E., deviation 11° 20′ E., variation of compass 28° W. Afterwards sailed during the next 24 hours as follows:—

K.	$\frac{1}{10}$	Courses.	Wind.	Leeway.	Deviation.
37	8	W.N.W.$\frac{1}{4}$E.	W.S.W.	2	11° 25′ W.
51	4	S.$\frac{3}{4}$W.	E. b. S.	$1\frac{1}{4}$	5° 30′ W.
37	7	N.N.E.$\frac{3}{4}$E.	N.N.W.	$1\frac{1}{2}$	8° 45′ E.
21	9	N.W.$\frac{1}{4}$N.	S.	$\frac{1}{4}$	4° 30′ W.

A current set the ship the last four hours by the compass S.W. at the rate of $3\frac{1}{4}$ miles per hour. Required the latitude and longitude in on June 16th at noon.

Section IV.

1. Define *departure*, and show accurately by a diagram how it is measured. Write down and prove the distinctive formula for middle latitude sailing.

2. What is the principle of Mercator's projection? Prove that—

$$(1.)\ \frac{\text{Diff. long.}}{\text{Mer. diff. lat.}} = \frac{\text{Dep.}}{\text{Tr. diff. lat.}}$$

$$(2.)\ \text{Tan. course} = \frac{\text{Diff. long.}}{\text{Mer. diff. lat.}}$$

$$(3.)\ \text{Distance} = \frac{\text{Tr. diff. lat.} \times \text{diff. long.}}{\text{Mer. diff. lat.}} \times \text{cosec. course.}$$

3. Obtain expressions for the latitude and longitude of the vertex of the great circle joining two places on the earth's surface.

What is the distance on a great circle between Lisbon, lat. 38° 42′ N., long. 9° 8′ W., and Cape Clear, lat. 49° 58′ N. long. 5° 11′ W.?

Section V.

1. Jan. 7, 1869, at a place in long. 87° 30′ W. the observed mer. alt. moon's L.L. was 25° 18′ 12″ (zenith N. of moon). Index cor. + 1′ 35″; height of the eye, 24 feet. Required the latitude.

2. Jan. 20, 1869, at 8h. 5m. a.m. mean time nearly, in lat. 52° 29′ N. and long. 15° 10′ W. the sun rose by compasss E. 56° 38′ S. Required the variation of the compass, the deviation being 7° 20′ E.

Section VI.

1. Define *equinoctial*, *ecliptic*, *obliquity of ecliptic*, *equation of time*, *amplitude*, *latitude*, and *longitude* of a heavenly body.

Illustrate by a projection on the horizon.

2. Shew how to compute the altitude of a heavenly body at a given place at a given time.

Ex.—Lat. 51° 30′ N. long. 3° 15′ W. Required the true alt. of the sun at 7h. 40m. a.m. on April 18, 1869. Required also the observed alt. given index cor.—3′ 20″; height of the eye 24 feet.

3. Show that the error in time arising from a small error in the observed alt. of the sun is least when the sun is on the prime vertical.

Section VII.

1. Feb. 20, 1869, at 5h. 30m. p.m. mean time nearly, the following set of sights was taken for determining the longitude, in lat. 26° 25′ S., long. by account 87° E:—

Time by chron.	Obs. alt: sun's L.L.	
1h. 4m. 56s.	12° 52′ 0″	Index cor. + 1′ 20″
1h. 5m. 14s.	12° 49′ 10″	Height of eye 30 ft.
1h. 5m. 32s.	12° 46′ 20″	

On Feb. 1, at Greenwich, noon, the chronometer was fast on G. M. T. 1h. 15m. 30s., and its rate was 2·8s. gaining.

2. March 4, 1869, in lat. by account 51° N., long. 33° W. the following double alt. of sun was observed:—

Mean time nearly.	Chron. time.	Alt. sun's L.L.	True bear.
10h. 50m. a.m.	11h. 15m. 20s.	30° 16′ 20″	S.S.E.
1h. 40m. p.m.	2h. 5m. 50s.	28° 26′ 10″	S.W.

The run of the ship in the interval was E. by S. 16 miles, the index cor. + 2′ 30″; height of the eye 30 feet. Required the true lat. at the second observation.

3. Aug. 14, 1869, at 6 p.m. mean time nearly, in lat. 38° 48′ N. long. 134° W., the height of the eye 17 feet, the following observations were taken:—

Obs. alt. sun's L.L.	Obs. alt. moon's L.L.	Obs. dist.
12° 16′ 45″	15° 16′ 50″	97° 12′ 40″
Index cor.—3′ 55″	+ 1′ 15″	+ 1′ 25″

Required the longitude.

SECTION VIII.

1. Describe the instrument by which the distance run at sea is obtained. How is the log line divided? What is the patent log?

If the glass runs out in 28s., what should be the length of the knot on the line?

2. Describe the azimuth compass. How is the bearing read off?

3. How do you ascertain that the index glass and horizon glass of a sextant are perpendicular to the plane of the instrument? The limb of a sextant contains 73°; what angle may be read off by it? Prove the property of the sextant on which this depends.

PRINCIPLES OF MECHANICS.

THREE HOURS ALLOWED.

1. What is the distinction between those forces to which the names *pressure*, *tension*, and *attraction* are respectively applied?

What is the English standard of weight, and how is it defined?

2. Explain what is meant by the transmission of force and give any illustrations of it which occur to you.

3. State the theorem which is commonly called the parallelogram of forces, and prove that it it is true for the *direction* of the resultant force.

Two forces act at an angle of 60°; the smaller one is 4. What must be the larger one, in order that the resultant may form with it an angle of 15°?

4. Define the moment of a force, and show that the sum of the moments of two forces acting in a plane about any point in that plane is equal to the moment of their resultant.

When the moment of the resultant vanishes, what conclusions do we draw?

5. What is the experimental law with regard to the extension of elastic strings?

An India-rubber string, 6 feet in length, is stretched by a weight of 50 lbs.; the quantity which measures the elasticity of the string is also 50 lbs. What will be the extension of the string?

6. What is the principle of the screw? Find the ratio between the power and weight—(1) if the screw be smooth; (2) if the screw be rough.

The length of a screw is 1¼ feet, in which space it makes 36 turns: the radius of the cylinder is 1½ inches; find the length of the thread.

7. Define moving force, and show that it is proportional to the statical efficiency of the same force.

A body weighing 100 lbs. is moved by a constant force which generates a velocity of 5 feet in one second. Find what weight the force would statically support.

8. A ball impinges upon a smooth horizontal plane; Find the motion of the ball afterwards.

A ball which is inelastic rolls down an inclined plane 120 feet long, whose slope makes an angle of 45° with a smooth horizontal plane. What will be its motion on this plane?

9. State and prove the three usual equations for the motion of a projected particle, acted on by an accelerating force in the direction of its motion.

A ball is thrown downwards with a certain velocity, on a horizontal plane, from a height of thirty feet; it rebounds 12 feet, then falls and rebounds 8 feet. Required the velocity with which it was thrown down.

10. Describe a diving bell; mention any contrivances for increasing its usefulness; what is the cause of the painful sensations which are experienced by those who are within it?

Find the height to which water would, if not otherwise expelled, rise in a diving bell, 8 feet high, whose lower lip is 100 feet below the surface of the water.

11. Prove that the surface of a fluid contained in a vessel which revolves uniformly around a vertical axis is a paraboloid.

A cylinder is 4 feet high, and its base has a diameter of 1 foot; it is filled to the depth of 3 feet with water. What will be the rate of revolution when the water just begins to be spilled?

12. Find the horizontal distance to which water will spout, through a small hole in the vertical side of a vessel. Example.—Let the vessel be 4 feet high, and the orifice half-way.

13. State D'Alembert's principle, and apply it to form the equations of motion of a rigid system.

(*To be continued.*)

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1870.

The thirty-ninth meeting of the Association was opened on Wednesday last, the 18th instant, at Exeter. The first meeting was one of the general committee, under the chairmanship of Dr. Hooker, the President of the last year's meeting. Reports were presented from the Council, from the Treasurer, and from the Kew Committee of the Association. The sectional officers and a committee of recommendation were appointed. Mr. Webster, Q.C., gave notice that, at the next meeting of the committee, he would move a resolution to the effect that towns which the Association decided to visit should have a voice in the election of President for the year. In certain neighbourhoods (he said) there were men of high position in the State whom it might be desired by the local hosts and others to have as President. He did not think it was right that such claims should be overlooked. In the case of Liverpool, for instance, to which place the Association was likely to go next year, the Earl of Derby and Lord Stanley were held in high esteem, and ought, one or other, to be considered. The Presidency (Mr. Webster declared) ought not always to be confined to men of science.

At eight o'clock in the evening, in the Victoria-hall, Dr. Hooker resigned the chair which he had held during the past year, and the new President, Dr. G. G. Stokes, Lucasian Professor of Mathematics at Cambridge, proceeded to deliver his opening address, of which the following is an abstract:—He began by explaining the objects for which the Association was instituted, its main feature being that it aims at giving a more systematic direction to scientific inquiry, and that in various ways. "It has, at various times, induced individuals who were more specially conversant with particular departments of science, to draw up reports on the present state of our knowledge in, or on the recent progress of, special branches. By thus ascertaining thoroughly what we already had, what we still wanted was made more clear; and, indeed, it was one special object of the reports I have mentioned to point out what were the more prominent desiderata in the various subjects to which they related. The Association was thus the better enabled to fulfil another of its functions, that of organising means for the prosecution of researches which require co-operation. An important part of the business of the Association is to organise committees for the prosecution of special researches, which are published at length. The Association also makes grants of money to individuals or committees for defraying the expenses of such researches. It appears from the report which is just published that, reckoning up to the year 1867 inclusive, the sum of £29,312 4s. 1d. has been voted by the Association for various scientific objects." In giving an account of the most recent progress of science, the President begun with astronomy, and referred to the fact that though "the motions and the masses of the heavenly bodies are revealed to us more or less fully by astronomical observations, we could not thus become acquainted with the chemical nature of these distant objects. Yet, by the application of the spectroscope to the scrutiny of the heavenly bodies, evidence has been obtained of the existence therein of various elements known to us by the chemical examination of the materials of which our own earth is composed; and not only so, but light is thrown on the state in which matter is there existing, which, in the case of nebulæ especially, led to the formation of new ideas respecting their constitution, and the rectification of astonomical speculations previously entertained." He then referred to observations for determining the motions of the stars commonly known as "fixed," but of which the fixity is not quite absolute. He explained how the science of optics had here come to the aid of astronomy, and he referred at considerable length to the observations of Mr. Huggins, especially upon the motion of Sirius, from which it appeared that that star and our sun are mutually receding from each other at the rate of 29·4 miles per second. He then spoke of the important results of the careful observations of the total eclipse of the sun on August 17th, 1868, especially those made with the spectroscope on "the remarkable mountain-like or cloud-like objects seen outside the dark disc of the moon," but which the study of the photographs obtained by Mr. Warren De La Rue proved to belong to the sun. Further spectroscopic observations of the sun, made by Mr. Lockyer with an instrument constructed for him by the late eminent optician, Mr. Cooke, were then described. "The prominences were thus shown to be merely elevated portions of an extensive luminous stratum of the same general character, which, now that the necessity of the interposition of the moon was dispensed with, could be traced completely round the sun. Meanwhile the same thing had been independently observed in another part of the world. After having observed the remarkable spectrum of the prominences during the total eclipse, it occurred to M. Janssen that the same method might allow the prominences to be detected at any time; and on trial he succeeded in detecting them the very day after the eclipse. The results of his observations were received shortly after the account of Mr. Lockyer's discovery had been communicated by Mr. De La Rue to the French Academy." . . . "One of the most striking results of the habitual study of these prominences is the evidence they afford of the stupendous changes which are going on in the central body of our system. Prominences, the heights of which are to be measured by thousands and tens of thousands of miles, appear and disappear in the course of some minutes. Moreover, these exhibitions of intense action are frequently found to be intimately connected with the spots, and can hardly fail to throw light on the disputed question of their formation. . . . I cannot leave the subject of astronomy without congratulating the Association on the accomplishment of an object which originated with it, and in the promotion of which it formerly took an active part. It was at the meeting of the Association at Birmingham in 1849, under the presidency of the Rev. Dr. Robinson, that a resolution was passed for making an application to Her Majesty's Government to establish a reflector, of not less than three feet aperture, at the Cape of Good Hope, and to make such additions to the staff of that observatory as might be necessary for its effectual working. Though the Association failed in its immediate object, its action in this matter has not remained fruitless. The subject has been warmly taken up at Melbourne, and after preliminary correspondence between the Board of Visitors of the Melbourne Observatory and the President and Council of the Royal Society, and the appointment by the latter body of a committee to consider and report on the subject, in April, 1864, a proposition was made to the Colonial Legislature for a grant of £5,000 for the construction of a telescope, and was acceded to. The telescope has been constructed by Mr. Grubb, of Dublin, and is now erected at Melbourne, and in the hands of Mr. Le Sueur, who has been appointed to use it. It is a reflector of four feet aperture, of the Cassegrain construction, equatorially mounted, and provided with a clock-movement. We may expect, before long, to get a first instalment of the results obtained by a scrutiny of the southern heavens with an instrument far more powerful than any that has hitherto been applied to them—results which will at the same time add to our existing knowledge, and redound to the honour of the colony, by whose liberality this long-cherished object has at last been effected." The president referred to the report of the committee, appointed at the meeting of the Association in 1862, consisting of representatives of the mechanical and chemical sections, for the purpose of investigating the application of gun-cotton to warlike purposes, and expressed his opinion that, "even with our present experience, there are some purposes for which gun-cotton can advantageously replace gunpowder, while its manufacture and storage can be effected with comparative safety, since it is in a wet state during the process of manufacture, and is not at all injured by being kept permanently in water, but merely requires to be dried for use. Even should it be required to store it in the dry state, it is doubtful whether, with the precautions indicated by the chemical investigations of Mr. Abel, any greater risk is incurred than in the case of gunpowder. In the blasting of hard rocks it is found to be highly efficient, while the remarkable results recently obtained by Mr. Abel leave no doubt of its value for explosions such as are frequently required in warfare. General Hay speaks highly of the promise of its value for small arms; but many more experiments are required, especially as a change in the arm and mode of ignition require a change in the construction of the cartridge. In heavy ordnance, the due control of the rapidity of combustion of the substance is a matter of greater difficulty; and, though considerable progress has been made, much remains to be done before the three conditions of safety to the gun, high velocity of projection, and uniformity of result, are satisfactorily combined. . . Last year Dr. Carpenter and Professor Wyville Thomson represented to the Royal Society the great importance to zoology and palæontology of obtaining soundings from great depths in the ocean, and suggested to them to use their influence with the Admiralty to induce them to place a gun-boat, or other suitable vessel, at the disposal of those gentlemen, and any other naturalists who might be willing to accompany them, for the purpose of carrying on a systematic course of deep-sea dredging. This application was acceded to. Dredging was successfully accomplished at a depth of 650 fathoms; and the existence was established of a varied and abundant submarine fauna, at depths which had generally been supposed to be either azoic, or occupied by animals of a very low type; and the character of the fauna and of the mud brought up was such as to point to a chalk formation actually going on. It seemed desirable to carry the soundings to still greater depths, and to examine more fully the changes of temperature which had been met with in the descent. Another application was accordingly made to the Admiralty in the present year, and was no less readily acceded to than the former; and a larger vessel than that used last year is now on her cruise. I am informed by Dr. Carpenter that dredging has been successfully carried down to more than 2,400 fathoms (nearly the height of Mont Blanc), and that animal life has been found, even at that depth, in considerable variety, though its amount and kind are obviously influenced by the reduction of temperature to Arctic coldness." The President then mentioned the movement that had been set on foot at a public meeting, presided over by H.R.H. the Prince of Wales, to erect a monument to Faraday. In chemistry, he referred to one or two discoveries which are extremely curious, and some of which may prove of considerable practical importance. "The Turaco or plantain-eater of the Cape of Good Hope has a portion of its wings of a fine red colour. This red colouring-matter has been investigated by Professor Church, who finds it to contain nearly six per cent. of copper, which cannot be distinguished by the ordinary tests, nor removed from the colouring-matter without destroying it. The colouring-matter is, in fact, a natural organic compound of which copper is one of the essential constituents. In the very same feather, partly red and partly black, copper was found in abundance in the red parts, but none, or only the merest trace in the black. . . . . In studying the transformations of alizarine under the action of chemical reagents, MM. Craebe and Liebermann were led to connect it with anthracene, one of the coal-tar series of bodies, and to devise a mode of forming it artificially. The discovery is still too recent to allow us to judge of the cost at which it can be obtained by artificial formation, which must decide the question of its commercial employment. But assuming it to be thus obtained at a sufficiently-cheap rate, what a remarkable example does the discovery afford of the way in which the philosopher, quietly working in his laboratory, may obtain results which revolutionise the industry of nations! . . ." "Another example of the way in which practical applications unexpectedly turn up, when science is pursued for its own sake, is afforded by a result recently obtained by Dr. Matthiessen, in his investigation of the constitution of the opium bases. He found that by the action of hydrochloric acid on morphia a new base was produced, which as to composition differed from the former merely by the removal of one equivalent of water. But the physiological action of the new base was utterly different from that of the original one. While morphia is a powerful narcotic, the use of which is apt to be followed by subsequent depression, the new base was found to be free from narcotic properties, but to be a powerful emetic, the action of which was unattended by injurious after-effects. It seems likely to become a valuable remedial agent. In relation to mechanism, this year is remarkable as being the centenary of the great invention of our countryman, James Watt. It was in the year 1769, that he took out his patent involving the invention of separate condensation, which is justly regarded as forming the birth of the steam-engine. Little could even his inventive mind have foreseen the magnitude of the gift he was conferring on mankind in general, and on his own country more particularly. In these days of steamers, power-looms, and railways, it requires no small effort to place ourselves, in imagination, in the condition we should be in without the steam-engine."

The President concluded as follows:—

"With reference to those branches of science in which we are more or less concerned with the phenomena of life, my own studies give me no right to address you. I regret this the less because my predecessor and my probable successor in the presidential chair are both of well-known eminence in this department. But I hope I may be permitted as a physicist, and viewing the question from the physical side, to express to you my views as to the relation which the physical bear to the biological sciences.

"No other physical science has been brought to such perfection as mechanics; and in mechanics we have long been familiar with the idea of the perfect generality of its laws, of their applicability to bodies organic as well as inorganic, living as well as dead. Thus, in a railway collision, when a train is suddenly arrested, the passengers are thrown forward, by virtue of the inertia of their bodies, precisely according to the laws which regulate the motion of dead matter. So trite has the idea become that the reference to it may seem childish; but from mechanics let us pass on to chemistry, and the case will be found by no means so clear. When chemists ceased to be content with the mere ultimate analysis of organic substances, and set themselves to study their proximate constituents, a great number of definite chemical compounds were obtained which could not be formed artificially. I do not know what may have been the usual opinion at that time among chemists as to their mode of formation. Probably it may have been imagined that chemical affinities were indeed concerned in their formation, but controlled and modified by an assumed vital force. But as the science progressed, many of these organic substances were formed artificially, in some cases from other and perfectly distinct organic substances, in other cases actually from their elements. This statement must indeed be accepted with one qualification. It was stated several years ago, by M. Pasteur, and I believe the statement still remains true, that no substance the solution of which possesses the property of rotating the plane of polarisation of polarised light had been formed artificially from substances not possessing that property. Now several of the natural substances which are deemed to have been produced artificially are active, in the sense of rotating the plane of polarisation; and therefore in these cases the inactive, artificial substances cannot be absolutely identical with the natural ones. But the inactivity of the artificial substance is readily explained, on the supposition that the artificial substance bears to the natural the same relation as racemic acid bears to tartaric,—that it is, so to speak, a mixture of the natural substance with its image in a mirror. And when we remember by what a peculiar and troublesome process M. Pasteur succeeded in separating racemic acid into the right-handed and left-handed tartaric acids, it will be at at once understood how easily the fact, if it be a fact, of the existence in the natural substance of a mixture of two substances, one right-handed and the other left-handed, but otherwise identical, may have escaped detection. This is a curious point, to the clearing up of which it is desirable that chemists should direct their attention. Waiving then the difference of activity or inactivity, which, as we have seen, admits of a simple physical explanation, though the correctness of that explanation remains to be investigated, we may say that, at the present time, a considerable number of what used to be regarded as essentially natural organic substances have been formed in the laboratory. That being the case, it seems most reasonable to suppose that in the plant or animal from which those organic substances were obtained, they were formed by the play of ordinary chemical affinity, not necessarily nor probably by the same series of reactions by which they were formed in the laboratory, where a high temperature is commonly employed, but still by chemical reactions of some kind, under the agency, in many cases, of light, an agency sometimes employed by the chemist in his laboratory. And since the boundary line between the natural substances which have and those which have not been formed artificially is one which, so far as we know, simply depends upon the amount of our knowledge, and is continually changing as new processes are discovered, we are led to extend the same reasoning to the various chemical substances of which organic structures are made up.

"But do the laws of chemical affinity, to which, as I have endeavoured to infer, living beings, whether vegetable or animal, are in absolute subjection, together with those of capillary attraction, of diffusion, and so forth, account for the formation of an organic structure, as distinguished from the elaboration of the chemical substances of which it is composed? No more, it seems to me, than the laws of motion account for the union of oxygen and hydrogen to form water, though the ponderable matter so uniting is subject to the laws of motion during the act of union just as well as before and after. In the various processes of crystallisation, of precipitation, and so forth, which we witness in dead matter, I cannot see the faintest shadow of an approach to the formation of an organic structure, still less to the wonderful series of changes which are concerned in the growth and perpetuation of even the lowliest plant. Admitting to the full as highly probable, though not completely demonstrated, the applicability to living beings of the laws which have been ascertained with reference to dead matter, I feel constrained at the same time to admit the existence of a mysterious something lying beyond—a something *sui generis*, which I regard, not as balancing and suspending the ordinary physical laws, but as working with them and through them to the attainment of a designed end.

"What this something, which we call life, may be, is a profound mystery. We know not how many links in the chain of secondary causation may yet remain behind; we know not how few. It would be presumptuous indeed to assume in any case that we had already reached the last link, and to charge with irreverence a fellow-worker who attempted to push his investigations yet one step further back. On the other hand, if a thick darkness enshrouds all beyond, we have no right to assume it to be impossible that we should have reached even the last link of the chain; a stage where further progress is unattainable, and we can only refer the highest law at which we stopped to the fiat of an Almighty Power. To assume the contrary, as a matter of necessity, is practically to remove the first cause of all to an infinite distance from us. The boundary, however, between what is clearly known and what is veiled in impenetrable darkness is not ordinarily thus sharply defined. Between the two there lies a misty region, in which loom the ill-discerned forms of links of the chain which are yet beyond us. But the general principle is not affected thereby. Let us fearlessly trace the dependence of link on link, as far as it may be given us to trace it, but let us take heed that in thus studying second causes we forget not the First Cause, nor shut our eyes to the wonderful proofs of design which, in the study of organised beings especially, meet us at every turn.

"Truth, we know, must be self-consistent, nor can one truth contradict another, even though the two may have been arrived at by totally different processes, in the one case, suppose, obtained by sound scientific investigation, in the other case taken on trust from duly authenticated witnesses. Misinterpretations of course there may be on the one side or on the other, causing apparent contradictions. Every mathematician knows that in his private work he will occasionally, by two different trains of reasoning, arrive at discordant conclusions. He is at once aware that there must be a slip somewhere, and sets himself to detect and correct it. When conclusions rest on probable evidence, the reconciling of apparent contradictions is not so simple or certain. It requires the exercise of a calm, unbiassed judgment, capable of looking at both sides of the question; and oftentimes we have long to suspend our decision, and seek for further evidence. None need fear the effect of scientific inquiry carried on in an honest, truth-loving, humble spirit, which makes us no less ready frankly to avow our ignorance of what we cannot explain than to accept conclusions based on sound evidence. The slow but sure path of induction is open to us. Let us frame hypotheses if we will; most useful are they when kept in their proper place, as stimulating inquiry. Let us seek to confront them with observation and experiment, thereby confirming or upsetting them as the result may prove; but let us beware of placing them prematurely in the rank of ascertained truths, and building further conclusions on them as if they were.

"When from the phenomena of life we pass on to those of mind, we enter a region still more profoundly mysterious. We can readily imagine that we may here be dealing with phenomena altogether transcending those of mere life, in some such way as those of life transcend, as I have endeavoured to infer, those of chemistry and molecular attractions, or as the laws of chemical affinity in their turn transcend those of mere mechanics. Science can be expected to do but little to aid us here, since the instrument of research is itself the object of investigation. It can but enlighten us as to the depth of our ignorance, and lead us to look to a higher aid for that which most nearly concerns our wellbeing."

The Earl of Devon moved a cordial vote of thanks to Professor Stokes, for his able address, which was seconded by Sir Stafford Northcote, and carried by acclamation. The Mayor of Exeter welcomed the society to the city. The Secretary stated that the number of tickets sold amounted to 1,583.

EDUCATION IN HOLLAND.

The *Times* correspondent, in describing the portion of the Amsterdam Exhibition illustrative of education, says:—"Class 6, that of instruction, is extensively represented, and gives a good idea of the results of Dutch middle-class education, the system of which appears very complete, and is not, apparently, hampered by political prejudices or religious intolerance. A large aisle of the building is completely filled with plans, sections, models, drawings, straw plaitings, and other works from the Amsterdam "Ambacht," or trade schools, and the communal schools of the different towns. The *élèves* of the Zaandam and the Zutphen Burg-Avond schools appear to excel in clay modellings for house decorations, such as friezes and cornices. Deventer sends particularly good wood carving; Rotterdam, sections and building plans; Breda, graceful models in red clay. All the Holland towns are represented, though it is needless to specify the name of each. Education is not compulsory, although the practical results prove that it has reached everybody, and small facts show how deeply the love of knowledge is rooted in the people. The lad in the billiard *café*, who attends to the wants of the players, may be seen, in the intervals of fetching beer and coffee, at his writing lesson; and in the national collection of paintings at the Trippenhuis no inconsiderable portion of the visitors are young boys, who may be noticed deeply engrossed in the pictures and the descriptive explanations given in the catalogues. While government in Holland provides that education shall knock at the doors of everybody, it does not in the least seek to compete or interfere with private undertakings, except that they are obliged to be classified and inspected as primary or middle schools, according to the grade of education they offer. Dutch education has been mostly the growth of the present century, and is principally owing to the establishment, in 1784, by a Baptist minister, of the Society for the Promotion of the Public Weal (*Maatschappi Tot Nut van't Algemeen*), which, commencing on a very humble scale, now numbers 200 branch societies and 14,000 members. Some excellent work in straw and wool is shown by one of their industrial schools for young girls, who for 15 florins a year (£2 1s. 8d.) are taught, during the course of three years, a thoroughly sound education, followed by a special one for any particular branch, such as drawing, dressmaking, engraving, or even pharmacy. The "Ambacht" schools for boys are founded much upon the same system. Each lad choses his trade and is taught it, and after the expiration of a certain time is apprenticed and helped out. The first great educational law of Holland was passed in 1806, and principally took in hand primary education. In 1857, this law was much extended, and, in 1863, was applied to middle instruction. Very great success attended the foundation of these secondary schools, which were established especially for artisans, who, after going through their educational course in them, were enabled to ascend a step higher and enter the Ecole Polytechnique of Delft.

"With regard to the educational display of other countries, England shows various official documents connected with past exhibitions. Mr. Davidson has a collection of drawing models and educational books for workmen, and Mr. Dean an infinite variety of picture-books for young ideas. It is a curious fact that, notwithstanding the literary activity of Amsterdam, a great portion of these children's books are printed in the Dutch language by Mr. Dean, and largely circulated in Holland. From Belgium, the Ecoles Professionelles des Jeunes Filles at Brussels have a goodly exhibit of drawings, models, and ornamental work; while there is a still more interesting show from the Crèche Ecole Gardienne at Antwerp. It is a most significant fact to note how these little ones, varying in age from six months to six years, are taught to be useful on the Froibel system, and we cannot but regret that some such institution is not attempted in this country."

Fine Arts.

PARIS EXHIBITION OF APPLIED ART.—The Exhibition of the Union Centrale of the Fine Arts Applied to Industry opened, as announced, on the 10th inst.; and although there are some vacancies to be filled up, and some arrangements yet to be made, the exhibition is highly important and interesting. The number of exhibitors in the first division of the collection, namely, that of manufactured products, is about four hundred, but that number does not express the value of the exhibition. Nearly all the exhibitors are of the first class; and the collections are generally large as well as choice. Furniture forms, naturally, a prominent subdivision, and most of the examples shown belong to the purer styles which have of late years become fashionable in France. Elaborately inlaid work of all kinds is becoming rare. Amongst the novelties may be noticed some painted bed-room furniture, simple and elegant in form, and very pleasing in colour— a greyish blue picked out with white. The collection of china *faïences* and terra-cotta work is large and good, the most remarkable being imitations or variations of Chinese ware, which has been quite the rage in France of late; and as the models selected are generally of the best kind, this fashion is doing good service to ceramic manufacture. The collection of mosaic and other kinds of paving is also good, especially as regards the colouring, which is generally unobtrusive and agreeable to the eye. There are also some very well executed wall-tiles, after Eastern types—a reflection of the Great Exhibition of 1867. The Baccarat Works contribute two immense moulded glass vases, about five feet high, of good colour and admirable workmanship; and there are some specimens of enamelled glass vases, by M. Brocard, which are well deserving of attention. The works in bronze, real and imitation, and the ornamental productions generally are well worthy of the reputation of the Parisian artists and manufacturers. The exhibition of the works of the schools of art, mostly shown in competition for prizes offered by the Society, bears evidence to the great attention paid to drawing all over the country; while the original models and designs for manufactured articles show the results of such teaching. Many of the flower designs for fabrics are of great beauty. The retrospective portion of the exhibition consists, on the present occasion, of oriental productions of all kinds and of all ages, and is the first exhibition of the kind attempted. The collection is very large, nearly as large as that of the china, *faïences*, and enamels shown by the same society in 1865, and is particularly rich in Persian, Broussa, Indian, Chinese, and Japanese works. We shall have to return again to the subject, but we desire, at the outset, to draw the special attention of English designers and students to this important collection of the works of their neighbours, which well deserves study.

Commerce.

INDIAN TEA.—The *Produce Markets' Review* says that the Chinese teas " have now to encounter a formidable rival in the production of India, which has made vast strides both in the quantity of tea produced, and in the improvement of its manufacture. Some two or three years ago, it was comparatively rare to find a grocer using Indian tea to any extent, but during the last twelve months, owing mostly to the inferiority of China teas, the grocer has been compelled to use it largely, and it would appear that the public are so satisfied with the change that, in some parts of the kingdom, more than two-thirds of Indian tea are used to one of China, and it is doubtful if the public, having once been accustomed to the peculiarly rich flavour and pungency of Indian teas, will ever be satisfied with the comparatively negative quality of China teas. In other parts of the country the taste is spreading, much, we are assured, to the benefit of the grocery trade."

Colonies.

AGRICULTURE IN SOUTH AUSTRALIA.—The agricultural statistics for the harvest 1868-9, published by the government statist, prove very disappointing. In the early part of the season confident expectations were put forth that the average yield must be at least twelve bushels per acre. The crops, however, did not turn out so well as they promised, and the actual average was only 9⅔ bushels per acre. This is very much below the average of the five years prior to last year, which was about twelve bushels per acre. The following table shows the average under wheat, the total produce and average price during the year for five years:—

	Acreage.	Produce.	Average price for the year.
1863-4	335,758	4,691,919	4s. 10d.
1864-5	390,836	4,252,949	7s. 10d.
1865-6	410,608	3,587,800	8s. 7d.
1866-7	457,628	6,561,415	6s. 2d.
1867-8	550,056	2,571,894	4s. 5d.

This year the number of acres under wheat cultivation is 532,654, or 17,802 acres less than the previous year. This fact supports the theory that after a good harvest the average of wheat sown is higher, and after a bad harvest, less.

Notes.

REGISTRATION AND INSURANCE OF LETTERS CONTAINING BILLS, &C., BETWEEN FRANCE AND BELGIUM.—An imperial decree has recently appeared in the *Journal Officiel de France*, announcing an arrangement by which letters containing bills and other valuable documents passing between Belgium, France, and Algeria, may be registered, and their value insured to the amount of two thousand francs, in case of loss or robbery. The contents of the letter must be declared by the sender, who, in addition to a fixed charge of fifty centimes and the postage of the letter, pays a tax of twenty centimes on every hundred francs or fraction of a hundred francs insured.

PARLIAMENTARY REPORTS.

SESSIONAL PRINTED PAPERS.

Par. Numb.

Delivered on 5th August, 1869.

154. Bill—Endowed Schools (No. 2) (as amended on Re-commitment).
254. „ Broughty Ferry Provisional Order Confirmation.
258. „ Millbank Prison.
259. „ Straits Settlements.
261. „ Sanitary Act (1866) Amendment (Ireland).
316. Transits of Venus (1874 and 1882)—Correspondence.
349. Bank Notes – Return.
367. Hypothec (Scotland)—Report from the Select Committee of the House of Lords.
388. Constabulary (Ireland) Firearms—General Instructions.
Public General Acts—Chap. 43 to 57.

Session 1868.

464. Civil Service—Return.

Delivered on 6th August, 1869.

260. Bill—Attorneys and Solicitors' Remuneration.
344. Naval Prize Money, &c.—Account.
347. Vessels – Return.
359. (I.) Friendly Societies—Return.
374. Military Savings Banks—Account.
Standards Commission—Second Report.

Delivered on 7th August, 1869.

262. Bill—Benefit Building Societies Regulation.
263. „ Bishops Resignation (amended).
264. „ Habitual Criminals (amended).
343. Naval Hospitals—Report.
367. (I.) Law of Hypothec in Scotland—Supplementary Appendix to Report.
386. Despatch of Business in Parliament—Report.
389. Lunatics, &c. (Irish Asylums)—Returns.

Delivered on 9th August, 1869.

265. Bill—Parochial Schools (Scotland) (as amended on Consideration).
46. (V.) Trade and Navigation Accounts (corrected pages).
337. (A I.) Poor Rates and Pauperism—Return (A).
400. Roehampton Gate (Richmond Park)—Further Correspondence.
381. New Law Courts – Report and Evidence.

Patents.

From Commissioners of Patents' Journal, August 13.

Grants of Provisional Protection.

Agricultural implements—2122—M. Jack.
Ammonia, &c., extracting—2153—A. Rollason.
Animal fatty bodies, preparing and producing certain new—2157—H. Mège.
Artificial fuel, machinery for manufacturing—2317—F. A. Yeo and H. Hanna.
Block calendars, &c.—2297—W. R. Lake.
Bottles, apparatus for stoppering—2324—T. Grace.
Brads, apparatus for holding and driving—2213—H. E. Newton.
Bricks, &c., machinery for making—2063—W. Hutchinson.
Buckles for articles of dress—2305—C. N. Eyland.
Carriage axles—2273—M. J. Frisbie.
Chairs, &c., applying springs to—2292—D. R. Kilpatrick.
Coal tar products, manufacturing certain—2222—J. Rowley.
Curry combs—2325—W. E. Gedge.
Dyes—2075—J. Walker and P. A. Godefroy.
Electro-telegraphic apparatus—2281—W. A. Lyttle.
Engravings, reproducing on wood through aqua fortis—2299—A. Paténe, F. Bardoux, and G. Jurie.
Fabric, new textile—2336—J. Booth and R. W. Morrell.
Fabrics, dyeing certain textile—2312—S. M. Smith.
Fabrics, fixing colours on textile—2295—J. S. Kipping.
Fabrics, fluted, &c—1735—G. E. King.
Flax and hemp, utilising the waste of 2289—H. S. Heyman.
Flax, &c., machinery for scutching, &c.—2291—J. Tate.
Gas, apparatus for manufacturing—2309—T. Ramsay.
Gas meters—2319—J. Pinchbeck.
Harvesting machines, grinding the knives of—2285—A. V. Newton.
Insulating moulding and stands for walls and household furniture for the prevention of vermin—2266—W. W. Roberts.
Life belts—2104—C. A. G. de Liancourt.
Locomotive engines—2314—J. Sharrocks.
Looms—2260—J. Holding and J. Eccles.
Lubricators—2293—W. E. Gedge.
Lubricators—2303—F. Jackson.
Manures, &c., manufacturing—2327—J. T. Way.
Measures, apparatus for regulating, &c., the standards of—2340—A. Tylor.
Metal tubes, machinery for manufacturing—2294—T. F. Taylor.
Meters for measuring liquids and gases—2346—B. J. B. Mills.
Mines, &c., apparatus for ventilating—2318—M. Henry.
Organs—1296—R. Flower and M. M. Crowly.
Pills, &c., apparatus for mixing substances for—2306—B. Goddard and W. Finley.
Puddling furnaces, &c.—2020—T. Smith.
Purses, &c., fastening for—2117—C. Shether.
Rail or tramways, apparatus for indicating stations to passengers by—2301 C. and T. Watts.
Rails, girders, &c., machinery for rolling—2342—W. Brown.
Rotary gas exhausters—2330—I. Davies.
Rotary motion, &c., converting reciprocating rectilinear motion into—2321—C. D. Abel.
Safety lamps—2262—J. and J. Hyde.
Screw engines, gearing for auxiliary—2308—H. S. Edwards.
Sewing machines—2065—T. James.
Sewing machines—2304—J. M. Clements.
Shuttles, &c., pins, pirns, or bobbins for—2307—J. C. Milns and J. Sandiford.
Steam condensers—2300—J. B. B. Pinchon.
Steam engines—2298—G. Allibon.
Steam engines—2320—H. Turner.
Sugar-cane juice, apparatus for concreting—2302—D. Stewart.
Sugar-cane juice, mills for extracting—2316—W. Hosack.
Taps—2823 A. Louden.
Threads, machines for polishing—2326—C. Tuer, R. Howarth, and J. Pimbley.
Tobacco, twisting and rolling—2283—H. Gillan and G. Crawford.
Velocipedes—2344—J. U. Fairbairn.
Woollen cloth, machinery to be applied to the cards employed for raising the nap of—2143—J. E. Millar.
Woollen cloth, &c., raising gigs used in the process of raising the nap of—2219—J. Dawson and T. C. Fawcett.
Wrought-iron, process for re-working—2322—E. Beanes.

Inventions with Complete Specifications Filed.

Cartridges—2399—A. H. Brandon.
Fibrous materials, machinery for combing—2368—W. R. Lake.
Rock-boring machinery, &c.—2387—E. T. Hughes.
Vehicles, mechanism for the propulsion of—2333—F. C. Colney.

Patents Sealed.

465. T. Winder.
467. T. Billyeald.
470. V. A. Houdaille.
471. G. W. R. Pigott.
474. H Tylor.
481. J., B., and R. Wood.
482. E. T. Hughes.
488. W. R. Lake.
489. H. D. Bowyer and J. L. Norton.
493. A. Bartholomew.
494. A. Munro & W. B. Adamson.
496. J. D. Nichol and J. Eckersley.
501. D. G. Fitz Gerald.
508. W. M. Cochrane.
510. E. Dorsett.
511. A. Henry.
517. A. M. Clark.
521. W. R. Lake.
522. M. Mac Lennan.
532. J. H. Morl.
535. F. G. Fleury.
542. J. O. C. Phillips.
586. W. E. Newton.
590. W. R. Harris.
628. J. Hadley.
709. W. R. Lake.
1046. G. S. Chase.
1096. H. A. Bonneville.
1197. H. Aitken.
1822. J. G. Tongue.
1850. G. W. Fox.
1923. R. Caunce and M. G. and B. Bradley.

From Commissioners of Patents' Journal, August 17.

Patents Sealed.

497. C. Brook, L. Barker, and M. Thompson.
505. M. Vary.
513. J. Loader.
515. T Smith.
520. J. Barton.
527. J. Mabson.
528. A. Jacob.
537. R. Foster.
538. J. E. Lucas.
540. W. Ibotson, W. W. Ladelle, and A. G. Southby.
541. S. Osborn.
563. J Neilson and J. Marshall.
585. W. Parkinson.
591. W. T. Eley.
626. D. Davies.
649. W. Howes and W. Burley.
657. M. G. Cole.
707. W. R. Lake.
745. W. H. Clapp.
797. W. A. Lyttle.
835. E. A. Inglefield.
1156. C. T. Swanston.
1352. C. T. Liernur.
1467. W. A. Lyttle.
1610. R. Wheble.
1773. V. J. Four.
1826. A. W. Moss.
1861. J. Kirk, S. Shelmerdine, and C. Froggatt.
1941. F. C. Lecoultre.

Patents on which the Stamp Duty of £50 has been paid.

2060. M. A. Muir & J. McIlwham.
2269. E. Nelson.

Patents on which the Stamp Duty of £100 has been Paid.

2297. C. E. Spagnoletti.
2327. W. Whittle.